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USING PLANTS TO CLEAN UP CONTAMINATION

By Robert Cooke
STAFF WRITER

IN THE SEARCH to develop new ways to remove poisons left behind in the soil by the excesses of the industrial revolution, scientists are turning in an unlikely direction to find something — anything — to do the heavy lifting: They're looking to plants.

Usually, cleaning up soils contaminated with mercury, lead and other poisonous metals has involved "basically scooping them up, mixing them with cement and putting them in a landfill," said soil-scientist Scott Cunningham, at E.I DuPont de Nemours & Co., in Wilmington, Del.

But that is "incredibly expensive, and it can't be done for large areas," he said. "There's no hole big enough to throw Palmerston, Pennsylvania, [an area contaminated with mining and smelting residues] into."

One promising alternative, scientists now say, is to use the natural ability of plants to draw minerals from the ground to help cleanup sites contaminated by materials such as poisonous metals. The idea is to use cost-free solar energy to cleanup soil and water that are loaded with toxic substances.

Now, in laboratory studies at the University of Georgia and at Rutgers University in New Jersey, plants are being selected and, in some cases genetically engineered, to exploit their ability to metabolize metals without themselves being poisoned.

At Rutgers, plant biologist Ilya Raskin and his team have selected plants especially for their ability to separate metals, such as lead and chromium, from soil. A

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metal-hungry plant called Indian mustard is already being grown in field trials for this purpose.

"In many ways, living plants can be compared to solar-driven pumps which can extract and concentrate certain elements from their environment," Raskin and six colleagues wrote in a recent issue of Biotechnology magazine.

All plants, by necessity, have the ability to extract sustenance from the environment, including the soil and water. And some plants seem to extract extra elements — including cadmium, chromium, silver, lead and mercury — that they don't seem to need.

It's that extractive ability that's being exploited to retrieve poisonous metals dumped into the environment by industry, agriculture and transportation. In general, Raskin said, the technique is referred to as phyto-remediation.

Cunningham added that the field of phyto-remediation is growing rapidly because of new research, new needs and new technologies.

"The technology is coming along nicely," Cunningham said. Scientists are moving quickly to expand "our understanding of the different mechanisms that plants use to detoxify toxicants and protect themselves."

During phyto-remediation, Cunningham said, the plants become a "solar-driven extraction system." They remove metals from a "silica-aluminum-iron-based matrix, which is soil" and turn them into a "carbon-based form" that is more easily dealt with.

"We know how to get rid of carbon," he said. "You can do it with a match, we can eat the carbon away with microbes, or we can compost it" to recover the metals.

Cunningham noted that some plants with the spectacular ability to pick up and store poisonous metals have already been identified. "The most exotic is a tree in New Caledonia that has 25 percent nickel in its sap. It's a technique the plant has developed to defend itself against insects."

Other plants absorb metals and simply store them in bubble-like structures inside cells called vacuoles, out of harm's way. A vacuole is "sort of a cellular garbage can for things," Cunningham said, a way to keep dangerous metals out of contact with the cell's delicate internal machinery.

For ultimate disposal, valuable metals might be extracted for reuse from plant tissues such as stems and leaves. Or the plants can be burned and the residue collected for safer disposal. And some of the plants being studied for taking toxic mercury out of the soil will release the metal gradually, in very tiny amounts, to be safely dispersed in the air, the scientists said.

Raskin's biotechnology firm, Phytotech Inc., is also developing a water-cleansing process called rhizo-filtration. This involves growing plants hydroponically, letting their roots dangle in contaminated water to extract the metals that can be so poisonous.

"There will be a product on the market in two years in rhizo-filtration," Raskin said. "And there will probably be a product within the next four years in phyto-extraction," the use of plants to extract dangerous metals from soil.

The water-cleansing system — rhizo-filtration — is "extremely efficient, it's working already," Raskin added. A second-generation approach will involve insertion of new genes into the plants, further improving their ability to catch and collect toxic metals.

In contrast, genetic engineering is already the approach being pursued in Georgia. The most immediate target of geneticist Rich Meagher's work is the metallic mercury that has entered soils from agricultural lands, paper mills and similar sources.

Meagher and his team have already succeeded in getting new genes into their plants, which can now survive even in poisonous, mercury-rich conditions. The goal is to engineer the plants so they pull mercury out of the soil and then let it slowly drift away in the air.

Meagher's work takes advantage of genes already known to exist in microbes, genes that give bacteria the ability to live in environments that are too toxic for most living things. By moving these genes into plants and then growing the plants in contaminated areas, the Georgia team hopes to bring poisoned fields back into production and perhaps restore valuable soils in the process.

Meagher said that after years of work, his team has finally succeeded in getting one such metal-grabbing gene to perform properly in a favorite laboratory plant, Arabidopsis thaliana, a member of the mustard/cabbage family.

"The results were astounding — far better than we expected," Meagher said. "The surprising thing is that the plants aren't just a little bit resistant" to mercury, "they're incredibly resistant."

Normal, un-engineered plants growing on a mercury-tainted medium either died or grew very poorly, the researchers reported. In contrast, plants engineered with the special mer-A gene not only grew, they flourished. They were also able to pick up large amounts of mercury from the growing medium, he said.

The results also seem promising, he added, because "we've barely done anything to optimize this yet. There's a lot more we can do to improve its mercury-resistance."

The mer-A gene found in soil bacteria makes an enzyme, mercuric ion reductase, that transforms ionic mercury into a less toxic form that the plants can handle. But the plants still need to be tested further, and years may elapse before federal agencies, including the Environmental Protection Agency, allow the genetically engineered plants to be grown in open fields.

Nonetheless, Meagher said, if enough funding can be found to support research, and if the tests and experiments go as well as expected, the use of such plants "could have a huge environmental impact on any site contaminated with mercury and possibly other metals."

What isn't known yet, of course, is whether this approach to soil-cleansing will actually work where it's needed, on a large scale, outdoors, out in the field. "Is it practical to do with mercury? We just don't know," Meagher said.

Writing in Biotechnology, Rutgers' Raskin also pointed out that many of the areas where metals have poisoned soil are essentially barren, either because of the poisons or because the ground has been disturbed. As a result, the soils are subject to rapid erosion, and water leaches the metals out, spreading the toxic pollutants farther.

"A simple solution to stabilization of these wastes is re-vegetation with metal-tolerant plant species," Raskin wrote. This has already been done with some success, using local metal-tolerant plants, in contaminated mine wastes near Liverpool, England, he said.

The main incentive for this is the problem of cost. Using conventional techniques to clean up hazardous sites is expected to cost about $400 billion in the United States alone. And, Raskin said, the cost of cleaning up sites poisoned by heavy metals may be as high as $7.1 billion. The sites where heavy metals are combined with organic contaminants — such as solvents — will cost another $35.4 billion.

Because of such costs and the need to cleanse poisoned sites, Raskin said, there should be "an estimated $1 billion or more market in the U.S. and Europe by the year 2000." Customers will include the industries producing such wastes, as well as the local, regional and national governments stuck with correcting the mess.